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Publication Date

2018-06-01

DOI

10.1016/j.jaa.2018.03.003

Peer reviewed

Journal of Anthropological Archaeology 50 (2018) 85–97

Contents lists available at ScienceDirect

Journal of Anthropological Archaeology

journal homepage: www.elsevier.com/locate/jaa

Sheltered by reeds and settled on sedges: Construction and use of a twenty thousand-year-old hut according to phytolith analysis from Kharaneh IV, Jordan

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ARTICLE INFO

Keywords:
Human-environment interactions
Levant
Early Epipaleolithic
Domestic architecture
Brush huts
Tule technology
Phytoliths
Ethnographic analogy
Great Basin

ABSTRACT

This paper employs new phytolith evidence to consider how Early Epipaleolithic people at the site of Kharaneh IV (Azraq Basin, Jordan) used local plant resources to construct their huts, and furnish their indoor space. Forty-five sediment samples from Structure 1 were compared to previously published results (10 sediment samples) from the well-preserved site of Ohalo II (Hut 1) (adjacent to Sea of Galilee, Israel). Our results demonstrate that similar plant resources were employed in both sites' hut constructions, including the heavy use of wetland sedge and reed resources. Interpreting the extensive use of wetland resources in hut construction at Kharaneh IV required the use of new ethnographic analogs focused on wetland-based adaptations, such as Northern Paiute 'tule technology' from the American Great Basin. The phytolith evidence shows that woody and shrubby dicots were employed, likely to construct the hut frame. *Phragmites* culm may also have been used to frame the structure. While a variety of grasses, wetland reeds, and importantly sedge resources, were used as part of the hut superstructure, perhaps as bundled thatching to cover the frame. In the interior these resources were employed as a loose floor covering or matting to increase the comfort of the living space. Our broader findings emphasize that Early Epipaleolithic hunter-gatherers were increasingly investing in 'place'. Indeed, the construction of these early homes may even have enhanced the ecological productivity and social meaning of the Azraq Landscape.

1. Introduction

'*We shape our buildings and afterwards our buildings shape us*'
Winston Churchill

Late Pleistocene hunter-gatherers lived in a world largely unrecognizable from our own. Yet, we have inherited the consequences of a constructed environment rooted in the legacy of Epipaleolithic (ca. 23–11.5 ka cal. BP) innovation, including some of the earliest domestic architecture (Goring-Morris and Belfer-Cohen, 2008). Earlier Epipaleolithic (Early and Middle, ca. 23–14.5 ka cal. BP) structures are conceived generally as flimsy, perishable short-term builds or *huts*, as compared to the durable stone architecture or *homes* of the Late Epipaleolithic or Natufian period (Late, 14.5–11.5 ka cal. BP) (Maher et al., 2012a). However, the relatively ephemeral nature of Early and Middle Epipaleolithic structures, compared to later Epipaleolithic constructions, does not reflect the permanence of their occupation or their long-term use (Nadel, 2003). Indeed, several sites (Ohalo II and Kharaneh IV) from this period contain evidence for repeated long-term occupation (Maher et al., 2012a) but little evidence of the organic hut construction or perishable interior furnishings has survived because of poor botanical preservation. The exceptional organic preservation at the site of Ohalo II on the Sea of Galilee, Israel, is a unique exception (Nadel, 2003; Nadel et al., 2004; Nadel and Werker, 1999; Snir et al., 2015; Weiss et al., 2008).

This paper employs phytolith analysis to investigate how Early Epipaleolithic people at the site of Kharaneh IV in the Azraq Basin, Jordan, used local plant resources to construct their huts, and furnish their indoor space. Kharaneh IV is the largest Late Pleistocene site in the Levant (Fig. 1). Three hut structures identified at Kharaneh IV are the

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https://doi.org/10.1016/j.jaa.2018.03.003
Received 3 March 2017; Received in revised form 15 March 2018

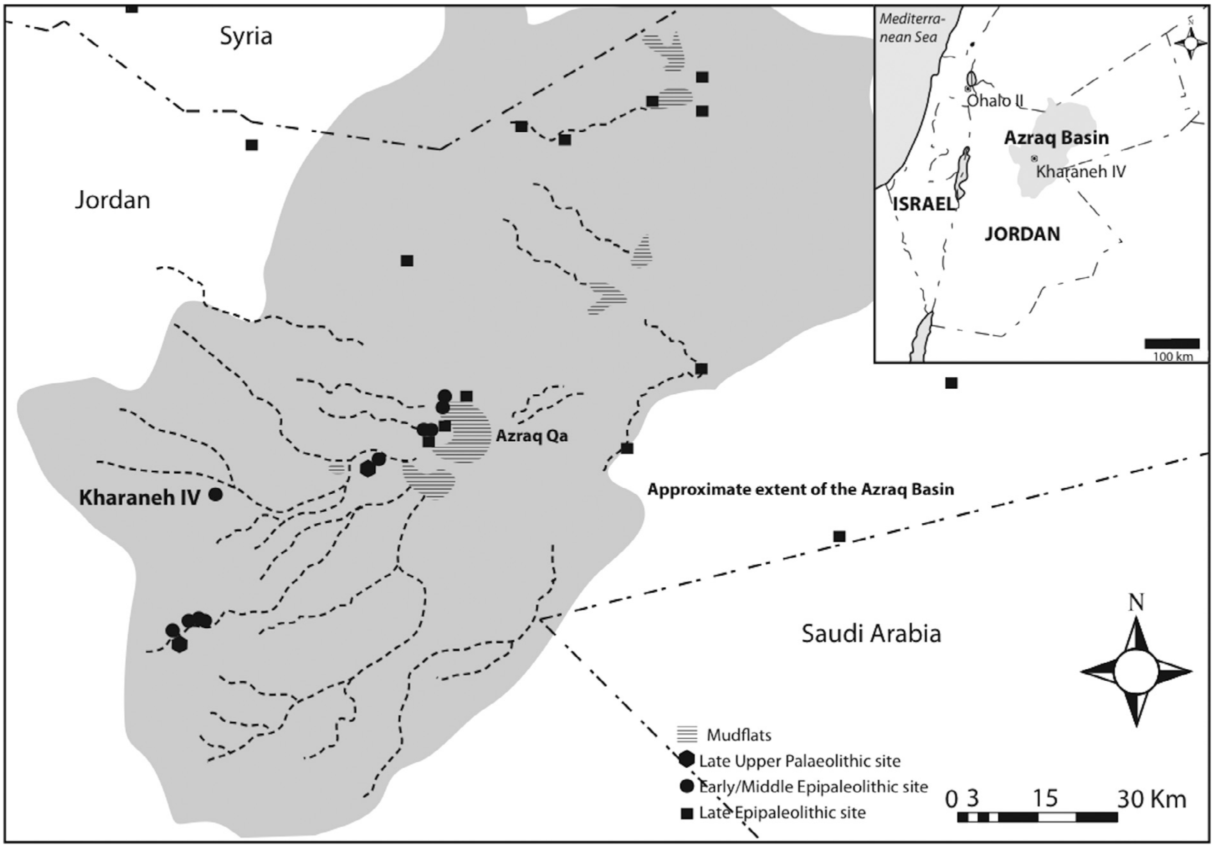

Fig. 1. Location map of Kharaneh IV and the location of other Epipaleolithic sites in the Azraq Basin.

earliest of their kind in the eastern Levant (Jordan) (Maher and Macdonald, 2013; Maher et al., 2012b). Structure 1 from Kharaneh IV provides samples for this exploratory analysis. The structure dates between 19.2 and 18.8 ka cal. BP (Maher et al., 2012b). By comparing the superstructure and floor contexts, we investigate what types of perishable plant materials were employed in the hut construction. Framing this new phytolith evidence with ethnographic evidence from the Great Basin and previously published macrobotanical and microbotanical evidence from Ohalo II provides a new perspective on Late Pleistocene Levantine domestic architecture. Moreover, we will consider the broader impacts and feedbacks associated with the construction of hut structures on the ecological and social landscape of the Azraq Basin.

2. Justification for the use of the Great Basin as an analog

The wetland/marsh environments that characterized the Azraq Basin during the Late Pleistocene facilitated increasingly sedentary occupation of large aggregation sites such as Kharaneh IV (Garrard and Byrd, 2013; Jones et al., 2016; Jones and Richter, 2011; Maher, 2016; Ramsey et al., 2016; Richter et al., 2013). Indeed, there is growing recognition that wetlands were a central focus for Levantine hunter-gatherer settlement and subsistence (Jones and Richter, 2011; Olszewski, 2000; Olszewski and Coinman, 1998; Ramsey et al., 2015, 2016, 2017; Ramsey and Rosen, 2016; Richter et al., 2013; Rosen, 2012, 2013). However, the use of wetland resources in hut construction, has received little consideration (Nadel, 2004; Portillo et al., 2010). Instead, scholars have emphasized brush hut construction, guided by ethnographic analogy to dryland hunter-gatherers in the African Kalahari Desert (Yellen, 1976) and the Central Australian Desert (Spencer and Gillen, 1998 [1898]).

These analogies have been drawn on the basis of archaeological evidence which suggests similarities in hut construction practices, and the limited available macrobotanical evidence (Ohalo II), which emphasizes the use of locally available trees and bushes (see Goring-Morris and Belfer-Cohen, 2008:242). However, more recent phytolith evidence from Ohalo II demonstrates that wetland materials were employed to a greater extent in the construction of Hut 1 than previously recognized (Ramsey et al., 2017).

In the eastern Levant, particularly in the Azraq Basin, we suggest that ethnographic analogies based on wetland/marsh adapted hunter-gatherers may provide better or additional insights. Therefore we also draw on evidence from the American Great Basin, with an emphasis on Northern Paiute tule technology (Fowler, 1990). Tule technology refers to the technological use of tules (sedges, reeds and cattails), a hallmark of Great Basin material culture (Fowler, 1990). While caution must be exercised when employing ethnographic analogy to the distant past, concentrating on the use of specific resources, in this case, wetland tule resources, can provide useful, ecologically constrained understandings.

3. Domestic architecture in the Levant during the Late Pleistocene

Hut structures are rare in the Late Pleistocene (Nadel and Werker, 1999) but their remains are evident at several early sites in the Levant. These sites include Ein Gev I, Azariq XIII, Jiita II, and Ohalo II in the Western Levant, and Kharaneh IV and Jilat 6 in the Eastern Levant (Garrard and Byrd, 2013; Goring-Morris and Belfer-Cohen, 2003; Maher et al., 2012a; Melki, 2004; Nadel and Werker, 1999; Stekelis and Bar-Yosef, 1965). Besides Kharaneh IV and Ohalo II, evidence of dwelling structures from this early period is limited to partially preserved floors, although post-holes have been identified at Jiita II (Goring-Morris and Belfer-Cohen, 2008). At Ohalo II, four of the six structures have been fully excavated, and two were sampled comprehensively (Nadel, 2003; Nadel et al., 2004). While at Kharaneh IV, thus far, one of the three identified structures has been fully excavated and a second is subject to ongoing excavations. At Kharaneh IV and Ohalo II, the identified structures are all kidney-shaped or sub-oval, ranging between 2 and 5 m

Fig. 2. Photograph from excavation of Ohalo II. Illustrating the level of macrobotanical preservation in the huts (L.15). Photograph credit, Dani Nadel.

in diameter, with semi-subterranean (ca. 20–40 cm deep) bowl-shaped profiles. The botanical evidence of architecture from Ohalo II will now be discussed in detail, including previously published phytolith evidence from Hut 1. Following which, the site of Kharaneh IV will be introduced and Structure 1 described.

3.1. Botanical evidence of architecture at Ohalo II

Ohalo II, on the edge of the Sea of Galilee, Israel, has unparalleled organic preservation and has been the focus of several comprehensive macrobotanical and microbotanical analyses (Nadel et al., 2012, 2004; Nadel and Werker, 1999; Piperno et al., 2004; Ramsey and Rosen, 2016; Ramsey et al., 2017; Snir et al., 2015; Weinstein-Evron et al., 2015; Weiss et al., 2008). The exceptional organic preservation at Ohalo II is mainly the result of inundation by rising water levels and lake sediments (Belitzky and Nadel, 2002; Tsatskin and Nadel, 2003). Hut 1, the largest and best preserved, featured three intact floor deposits and three major components, a hearth, specific working locales, and a sleeping area (Nadel et al., 2004).

At the base of the hut thick fragments (up to 5 cm in diameter) of tamarisk (*Tamarix*), willow (*Salix*), oak (*Quercus ithaburensis*), and smaller elements of a variety of species, including orach/seidlitzia (*Atriplex/Seidlitzia*) and mesquite (*Prosopis*), as well as unidentified leaves and grasses were recovered (Nadel et al., 2004; Snir et al., 2015) (Fig. 2). In addition, the remains of tens of thousands of seepweed (*Suaeda palaestina/fruticosa*) seeds were recovered in the hut, possibly originating from branches that formed the hut walls (Nadel and Werker, 1999).

Hut floors represent the continuous accumulation of debris within the structure. Floor cleaning was infrequent and may not have occurred at all (Nadel, 2003). Grass bedding consisting of *Puccinellia convoluta* bundles was found in Hut 1, at the bottom of floor III (Nadel et al., 2004; Tsatskin and Nadel, 2003). This degree of macrobotanical preservation of delicate grasses is unique.

With evidence for the use of a variety of locally available trees and bushes in the construction of the hut and no evidence for central poles, these huts, according to Goring-Morris and Belfer-Cohen (2003, 2008) are similar to the Kalahari San huts (Lee, 1979; Yellen, 1977), and may be best described as brush huts or *fond de cabane*, Thanks to the excellent botanical preservation of the hut construction materials at Ohalo II, these remains provide clues whereby we may characterize structures in other sites where botanical preservation is poor (Goring-Morris and Belfer-Cohen, 2008).

3.2. Phytolith evidence from Hut 1 (Loc. 1) at Ohalo II

In recent phytolith analysis of sediments from Hut 1 (Loci 1) at Ohalo II, we have demonstrated the importance of wetland plant resources, particularly reeds and sedges, to the construction or 'furnishing' of Hut 1 (Ramsey and Rosen, 2016; Ramsey et al., 2017). In particular, the ten phytolith samples (Table 1) from floor III feature large amounts of reed phytoliths and a generally high proportion of wetland-type taxa (Ramsey and Rosen, 2016), including sedges (Fig. 3) (all the data and identification methods underlying these findings are available in Ramsey et al., 2017). This evidence suggests that wetland plant resources, such as reeds and sedges featured more prominently in Early Epipaleolithic hut construction than macrobotanical remains alone suggest.

Table 1
Ohalo II, hut 1 Phytolith sample list.

Sample ID	Interpretation	Sample provenience
OH.14.8	Hut, floor III	Loc. 1, D80d, −212.5
OH.14.12	Hut, floor III	Loc. 1, E78d, −212.5
OH.14.15	Hut, floor III	Loc. 1, D81b, NW*, −212.44
OH.14.17	Hut, floor III	Loc. 1, D81b NE*, −212.44
OH.14.18	Hut, floor III	Loc. 1, D81b SW*, −212.44
OH.14.40	Hut, floor III	Loc. 1, E80b, −212.45–50
OH.14.45	Hut, floor III, grass bedding layer	Loc. 1, F79d, −212.51–.54
OH.14.46	Hut, floor III, grass bedding layer	Loc. 1, F79b, −212.49
OH.14.48	Hut, floor III, grass bedding layer	Loc. 1, F79b, −212.49–51
OH.14.49	Hut, floor III, grass bedding layer	Loc. 1, D80d SW*, −212.45
OH.14.5	Hut, below floor III	Loc. 1, D81b, −212.5

* Point samples taken from curated sediment blocks. All other samples were taken from previously collected bulk sediment samples.

4. Kharaneh IV

At 21,000 m^2 and ca. 1.5 m in depth, Kharaneh IV is notable for its phenomenal size. Kharaneh IV is one of several large, Early-Middle Epipaleolithic aggregation sites (including Jilat 6) in the Azraq Basin (Garrard and Byrd, 1992; Richter et al., 2013). On-site evidence demonstrates that during Kharaneh IV's earliest occupation it was located adjacent to, and at times inundated by, a local wetland environment, surrounded by semi-arid steppe/parkland (Jones et al., 2016, 2017; Ramsey et al., 2016).

In addition to the earliest documented hut structures in Jordan (Maher, 2011; Maher and Macdonald, 2013; Maher et al., 2012b), Kharaneh IV features a possible subfloor burial, worked bone objects, a ground-stone assemblage and perforated marine shells (Maher et al., 2012a; Richter et al., 2011a; Richter et al., 2013). These material remains provide evidence of increasing sedentism, the use of complex trade networks, sophisticated food processing, personal adornment

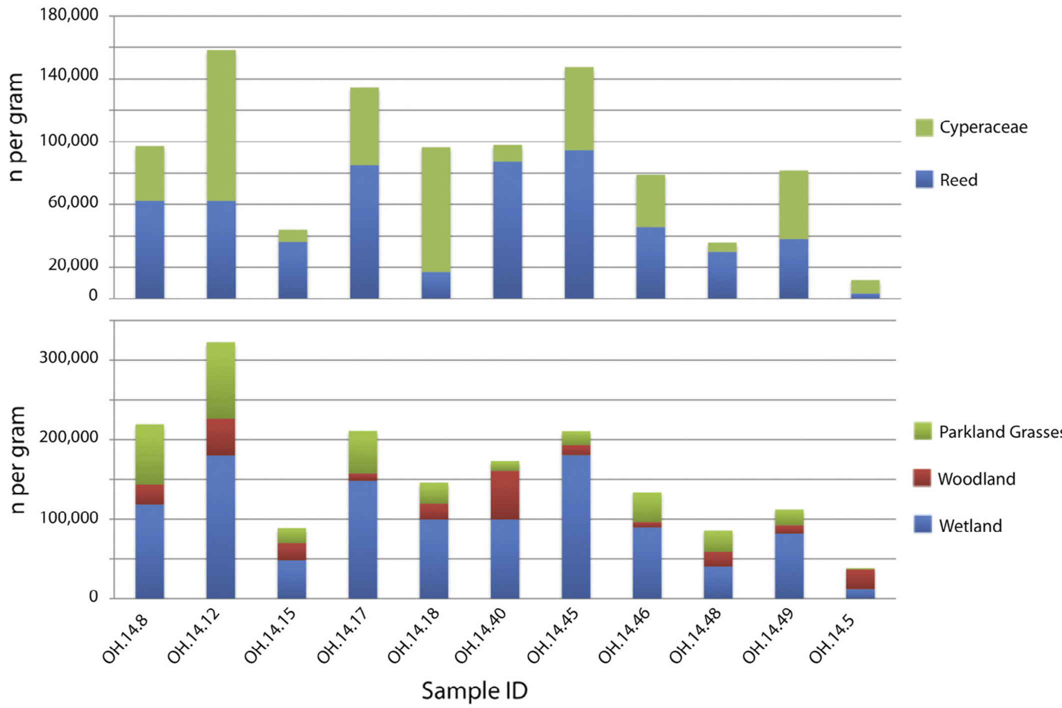

Fig. 3. Histogram comparing the phytoliths from Ohalo II, Hut 1. Above, Cyperaceae and Reed phytoliths per gram of sediment. Below, Ecozone-type phytoliths per gram of sediment. Wetland-type includes Cyperaceae cones, keystone ('fan-shaped') bulliforms, reed culm and leaf. Woodland-type includes all dicot forms. Parkland grass-type includes dendritic long-cells, papillae, cereal straw, all husk multi-cells. The data used in this figure are available in Ramsey et al. (2017).

Table 2
Kharaneh IV, Structure 1 deposit descriptions (Maher and Macdonald, 2013).

Loci	Interpretation	Description
220	Superstructure	Dark brown/black, loose, powdery sediment.
254	Superstructure	Compact reddish sediment patch with average density of finds. Differential burning of superstructure (mottled deposit within 220).
257, 271, 256	Superstructure	Compact grey/brown sediment patch with average density of finds. Differential burning of superstructure (overlies 232).
232	Superstructure/Floor	Dark reddish/brown loose sediment. Very frequent density of artifacts.
258	Floor	Compact dark orange/brown sediment with very frequent density of artifacts.
270	Floor	Compact orange sediment with very frequent density of artifacts.
261	Floor	Compact light, buff-colored clayey sediment with very frequent density of artifacts.
268	Ash Dump	Charred compact sediment with average density of artifacts. May represent the remnants of a hearth cleaning (overlies 261).

Fig. 4. Plan-view photograph of structure 1. In this photograph the southern-most part of the hut is not fully exposed. Photograph credit, EFAP Archive.

practices and possibly ritual behavior.

The Early Epipaleolithic occupation of Kharaneh IV includes three identified hut structures. Excavations during the 2010 field season uncovered two huts (Maher et al., 2010), while evidence for a third structure was found during the 2013 season (Maher et al., 2015; Maher and Macdonald, 2013). This third feature appears to crosscut Structure 1. Future excavations will investigate these deposits and establish the hut boundaries (Maher and Macdonald, 2013) (see Table 2).

4.1. Structure 1

Structure 1 is semi-subterranean (ca. 40 cm deep) and kidney-shaped in outline, measuring ca. 2.5 m (E/W) by ca. 3.5 m (N/S). The hut is characterized by several overlapping and superimposed occupational surfaces (Maher and Macdonald, 2013; Maher et al., 2012b). These floor deposits (ca. 2–3 cm thick) are at times ephemeral but are largely *in situ* and continuous, with a high density of artifacts, including several small caches of blades, bladelets, ochre and pierced shell, and articulated and disarticulated faunal remains (Maher et al., 2015, 2009,

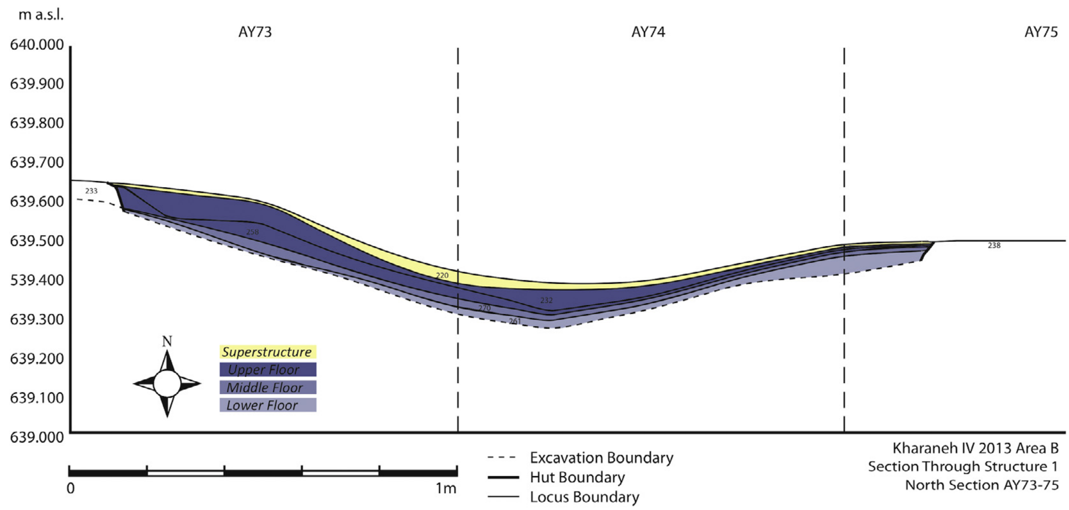

Fig. 5. Cross-section of structure 1. Superstructure and floor deposits are shown along with loci number.

2010). The materially rich floor deposits suggest that like Ohalo II, floor cleaning was infrequent, or possibly not practiced (Maher and Macdonald, 2013; Nadel, 2003). In addition, it has also been proposed that the larger artifact caches and installations (articulated shells and animal remains) were intentionally placed or staged prior to being interred and covered with a new floor (Maher et al., 2012b). In the north east of the hut are the remnants of an ash dump (L.268). In the north west section of the hut a piece of groundstone was recovered, associated with a concentration of unmodified rocks of a similar size. Another rock concentration was recovered in the southwest section of the hut (Maher and Macdonald, 2013). The superstructure deposits all tend to have high organic and charcoal concentrations, while the floor deposits all contain a high density of artifacts (Maher and Macdonald, 2013) (Table 2, Figs. 4 and 5). Floor deposits were also distinguishable from upper hut deposits due to their dense compaction, as well as *in situ* artifact and faunal remains deposited horizontally on the surfaces.

5. Methods

5.1. Excavation and sampling

This study includes 45 sediment samples (Table 3, Figs. 5 and 6) from the hut deposits (Structure 1), including superstructure and floor contexts. Excavations were conducted on a 1 × 1 m grid, with the units further divided into 25 cm × 25 cm sub-quadrants, which were assigned a letter designation, A through to P (see Fig. 6, AX73 to see sub-quadrant letter designation layout). Excavation was by cultural layers, which ranged from between 1 cm and 4 cm thick. Artifacts and faunal remains located on the surface of each context were point-provenienced to document their location. Phytolith samples were taken in 2013 from every context and every sub-quadrant. The samples analyzed in this paper represent only a fraction of the available material and were selected with the aim of providing a general vertical and horizontal coverage of the hut and to investigate Early Epipaleolithic construction and furnishing practices.

5.2. Phytolith methods

Phytoliths are microscopic, silt-sized silica particles. They are formed when plants take up soluble silica from ground water. The silica is then deposited in the cell wall and cell lumen (Hodson, 2016), creating durable inorganic silica 'casts' of the plants' internal structures. Grasses, sedges and palms (monocotyledons) readily produce phytoliths, often distinctive to plant family, genus and, more rarely, species (Pearsall, 2000; Piperno, 2006), providing key botanical evidence that is often poorly represented in even well-preserved macrobotanical assemblages (for example see Ramsey et al., 2017). Woody trees and other herbaceous dicots also produce phytoliths, but far fewer and with more irregular forms (Albert et al., 2000). Plants produce single-cell phytoliths or more heavily silicified suites of attached adjacent phytoliths, producing multi-cell forms, also known as silica skeletons. By studying the anatomical orientation of these fossilized sections of plant tissue, it is possible to make identifications down to the plant genus or species level.

Phytoliths were extracted from the sediments following Rosen (1999a, 1999b) protocol, which employs a series of techniques to remove carbonates, clays and organics, before extracting the phytoliths. Sieving the sediment though a 0.25 mm mesh removed the coarse sediment fraction. A sample of approximately 800 mg was taken for analysis. The sample was treated with 30 ml of 10% HCl to remove carbonates. To disperse the clays, a sodium hexametaphosphate solution (lab grade Calgon and distilled water) was added to the sample. The clays were removed from the sample by decanting after settling the fine sands and silts. This process was repeated until the suspense was clear. Organic matter was removed by dry ashing the samples in a muffle furnace for 2 h at 500 °C. The phytoliths were then extracted from the remaining fraction using density separation. A Sodium polytungstate (SPT) solution (with distilled water) calibrated to 2.3 specific gravity was used to separate the phytoliths from the heavier minerals. The phytoliths were then poured off, cleaned, weighed and mounted in Entellan.

The phytolith slides were counted at 400× magnification using a transmitted-light microscope. A minimum of 300 single-cells and 50 multi-cells were counted on each slide, with results expressed as number per gram of sediment. The absolute counts for each phytolith type were calculated using a modified version of the method outlined by Albert et al. (1999; Albert and Weiner, 2001; see Power et al. (2014) for details). This method allows consideration of the phytolith categories as independent variables rather than as interdependent proportions or percentages. Perhaps most critically, expressing our results as the number of phytoliths per gram of sediment allows us to evaluate phytolith density. This facilitates comparison between contexts, helping us to consider plant-use patterns.

6. Results and discussion

6.1. Phytolith results

All of the data underlying these findings are available in the accompanying supplementary data file. The phytoliths in Structure 1

Table 3
Kharaneh IV, Structure 1 Phytolith Sample List. The sample location number listed above refers to a particular sample location (sub-quadrant) illustrated in Fig. 6. The sample provenience first outlines the coordinates of each 1 m × 1 m unit with a N-S alphabetical and E-W numerical grid designation. The number that follows indicates the sample layer. The last letter indicates the sub-quadrant within the 1 m x 1 m unit.

Loci	Interpretation	Sample ID	Provenience	Sample location number
220	Superstructure	KH.14.1	AZ73.55.I	1
		KH.14.2	AZ74.55.O	2
		KH.14.3	AZ73.55.N	3
		KH.14.4	AY74.55.D	4
		KH.14.5	AY74.55.L	5
		KH.14.6	AY75.55.M	6
		KH.14.7	AY75.55.I	7
		KH.14.8	AX75.55.P	8
		KH.14.9	AX75.55.A	9
254	Superstructure	KH.14.10	AX75.22.G	10
		KH.14.11	AX75.22.L	11
		KH.14.12	AY74.57.C	12
257, 271, 256	Superstructure	KH.14.13	AY74.56.M	13
		KH.14.14	AW74.72.H	14
		KH.14.16	AX74.61.K	15
232	Superstructure/ Floor	KH.14.17	AY75.60.M	6
		KH.14.18	AZ74.60.P	16
		KH.14.19	AY73.60.F	17
		KH.14.20	AY73.60.H	18
		KH.14.21	AZ74.60.L	19
		KH.14.22	AX74.60.K	15
		KH.14.23	AY74.60.J	20
		KH.14.24	AX75.60.L	11
		KH.14.25	AX75.60.F	21
		KH.14.26	AW74.60.K	22
258	Floor	KH.14.36	AX74.61.I	23
		KH.14.37	AX74.61.O	24
		KH.14.38	AX74.61.F	25
		KH.14.39	AY74.61.J	20
		KH.14.40	AZ74.61.O	2
		KH.14.41	AY73.61.H	18
		KH.14.43	AZ73.61.N	3
270	Floor	KH.14.27	AZ73.71.I	1
		KH.14.28	AZ73.71.F	26
		KH.14.29	AZ74.71.P	16
		KH.14.30	AY73.71.G	27
		KH.14.31	AX74.71.F	25
		KH.14.32	AY73.71.A	28
		KH.14.33	AX74.71.E	29
		KH.14.34	AY74.71.N	30
		KH.14.35	AY74.71.H	31
261	Floor	KH.14.46	AZ74.66.P	16
		KH.14.47	AZ74.66.L	19
		KH.14.48	AY74.66.D	4
268	Ash Dump	KH.14.45	AZ74.68.K	32

appear to be well preserved, with the presence of delicate morphotypes such as hairs, and some large multi-cells, suggesting favorable preservation conditions. The phytolith assemblage in Structure 1 contains single-cell and multi-cell phytolith morphotypes for several plant types and parts. Single-cell monocot phytoliths are identified according to the ICPN classification system, where possible (Madella et al., 2005). Key morphotypes employed in this analysis include: monocot leaves and stems, indicated by single-cell and multi-cell psilate long cells; a variety of grass husks, indicated by dendritic long cells, both single-cell and multi-cell (Rosen, 1992). Other important identified taxa include, pooid grasses, indicated by rondel phytoliths, chloridoid grasses, indicated by saddles, and panicoid grasses, indicated by bilobes, quadralobes (crosses) and polylobes (Twiss et al., 1969). Single-cell and multi-cell keystone (fan-shaped) bulliforms commonly occur in grass species that favor watery habitats (Sangster and Parry, 1969), and at Kharaneh IV tend to compare favorably with reeds (Lu et al., 2006). More specific reed identifications include *Phragmites* sp. leaves and stems (also referred to as culms), which are indicated by characteristic multi-cell forms (Ryan, 2009, 2013). Cyperaceae (sedges), are indicated by single-cell and multi-cell cone morphotypes, and long cell and rod multi-cell forms (Ollendorf and Amy, 1992; Ollendorf et al., 1987). Dicot taxa are indicated by sheets, honeycomb, polyhedron and other irregular single-cell and multi-cell forms. The phytolith results are discussed by comparing the phytoliths from the superstructure and the floor deposits to investigate what kinds of plant materials were used to build Structure 1 (Fig. 7).

6.2. Hut construction according to phytolith evidence from Kharaneh IV

The phytolith evidence demonstrates that the superstructure deposits (average number per gram of sediment = 453,329) tend to have a slightly lower phytolith density than the floor deposits (average number per gram of sediment = 723,376) (Fig. 8). The presence of pooid, panicoid and chloridoid grasses demonstrates the use of grass resources in both the superstructure and floor deposits (Fig. 9). Notably, there does appear to be a slight increase in the absolute count of the grass morphotypes in the floor deposits. Moreover, by comparing the reed and sedge morphotypes (Fig. 10), it is apparent that the sedges increase as a component of the floor deposits relative to the superstructure deposits and other contexts (Fig. 11). The samples described as 'other contexts' include all of the Area A (Early Epipaleolithic) samples (non-hut contexts) published in Ramsey et al. (2016). The phytolith averages comparing superstructure, floor and non-hut contexts suggest that sedges were purposely placed on the hut floor, perhaps as a loose floor covering, or even matting or bedding, similar to Ohalo II (Nadel et al., 2004). Although the phytolith evidence suggests that sedges were employed to a greater degree at Kharaneh IV than at Ohalo II (see Figs. 3 and 10), perhaps reflecting the differing resources available in the marsh environment at Kharaneh IV versus the lake environment at Ohalo II (see Ramsey et al., 2016; Ramsey and Rosen, 2016).

The use of plant materials to increase the comfort of the hut interior may help explain the high concentration of cultural remains (artifacts) in the floor deposits. If the hut floors were covered with a loose layer of soft plant materials, including grasses and sedges, the accumulation of debris from indoor activities may have been simply 'swept under the rug'. Binford (1987) noted a similar phenomenon during his time with the Nunamiut. He describes the willow floors in the Nunamiut structures as an 'artifact trap' and a structural barrier for sweeping indoors (1987:496). It is clear that the hut at Kharaneh IV was not swept clean daily (see O'Connell et al., 1991 on the Hadza), but, rather, accumulated large quantities of cultural and plant materials (see Hardy-Smith and Edwards, 2004).

As previously noted, the phytolith evidence demonstrates that the hut superstructure was composed of a variety of plant materials, including grasses, sedges and reeds (Figs. 9 and 10). Importantly, diagnostic *Phragmites* sp. culm multi-cells appear to be more concentrated in the superstructure deposits than in the floor and other context deposits (Fig. 12). This suggests that *Phragmites* sp. was specifically a component of the superstructure. *Phragmites* sp. culms are very ridged and can reach heights of up to 6 m (20 feet). These characteristics, combined with their quantity and accessibility in the nearby marsh environment, means they would have been a potentially important construction material for framing and covering the huts.

While the evidence demonstrates that the inhabitants of Kharaneh IV used monocot resources, including grasses and wetland reeds and sedges, in the construction and furnishing of Structure 1, they also used dicot resources (Fig. 13). Combining all of the monocot phytoliths and comparing their density to the dicot phytoliths, indicates that both monocot and dicot resources feature prominently in the hut superstructure and floor deposits. This interpretation is based on the fact that

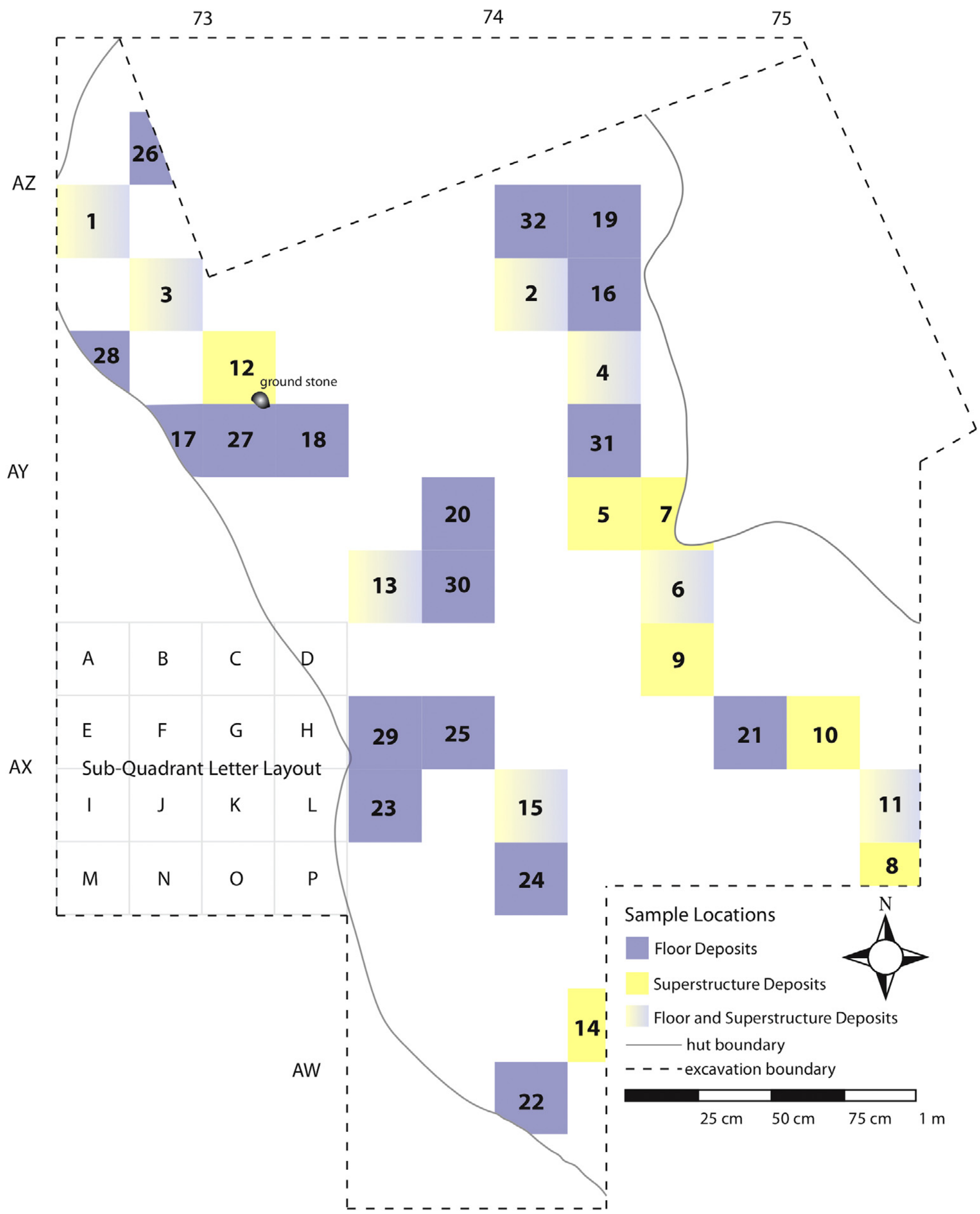

Fig. 6. Plan-view of structure 1. Superstructure and floor sample locations displayed. The numbers displayed in the sub-quadrants designate sample locations (sample location numbers). The particular samples taken from these locations and their complete provenience details are listed in Table 3. Sampled floor deposits are colored purple. Sampled superstructure deposits are colored yellow. When floor and superstructure deposits have both been samples from a particular sample location the sub-quadrant has been colored with a yellow-purple fade. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

monocots tend to produce far more phytoliths than dicots (Piperno, 2006). Consequently, while the dicot densities are much lower, they may actually represent a much larger proportion of the plant materials employed.

In sum, the phytolith evidence suggests that Structure 1 was constructed from a variety of plant species. The superstructure, as at Ohalo II, likely had a woody dicot frame covered with a variety of shrubby herbaceous dicots. This interpretation fits the pattern described for other huts from this period (Goring-Morris and Belfer-Cohen, 2003, 2008). However, phytolith analysis demonstrates that a great variety of grasses and wetland reeds and sedges were used in the construction at Kharaneh IV and Ohalo II, likely as thatching to cover the dicot frame. Importantly at Kharaneh IV, *Phragmites* sp. culms may also have been used to frame and cover the structure. The phytolith evidence also indicates that the floor of Structure 1 (Kharaneh IV) was covered in a layer of soft vegetation that included grasses and sedges. This vegetation likely represents purposeful floor covering and furnishing of the hut interior, perhaps even formal matting and bedding. These findings demonstrate the important contribution that phytolith analysis can make. Indeed, at most Late Pleistocene sites, phytolith evidence is the only source of evidence for such delicate plant remains.

6.3. Additional insights from the Great Basin: tule house construction

The phytolith evidence from Structure 1 demonstrates that the Early Epipaleolithic inhabitants at Kharaneh IV built their homes from a variety of local plant resources. In line with Ohalo II, the only other example of hut construction during this period in the Levant with direct botanical evidence (Nadel et al., 2004; Nadel and Werker, 1999; Ramsey and Rosen, 2016; Ramsey et al., 2017), it is possible that at Kharaneh IV, woody and shrubby dicots, evidenced from the phytoliths, may have been used to construct a frame. Phytolith evidence demonstrates that a variety of grasses, and wetland reed and sedge resources, were used as part of the hut superstructure, likely as bundled thatching to cover the frame, and in the interior, likely as a loose floor covering or matting to increase the comfort of the living space. The extent to which grass, but more importantly, wetland reed and sedge resources were utilized, suggests that ethnographic examples drawn from the Great Basin, a region that employs 'tule technology', may provide additional insights.

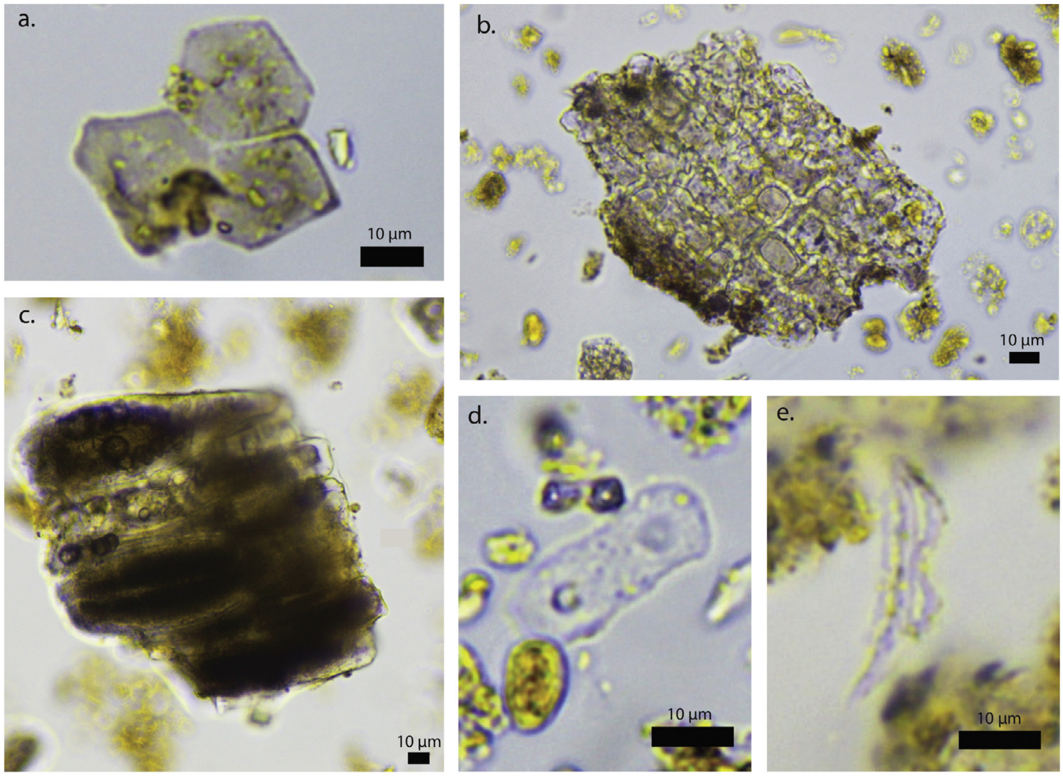

Fig. 7. Phytolith microfossils from Kharaneh IV, Structure 1. a. sedge cones; b. grass husk; c. stacked keystone bulliforms (cf. reed leaves); d. sedge cones; and e. sedge cones (side view).

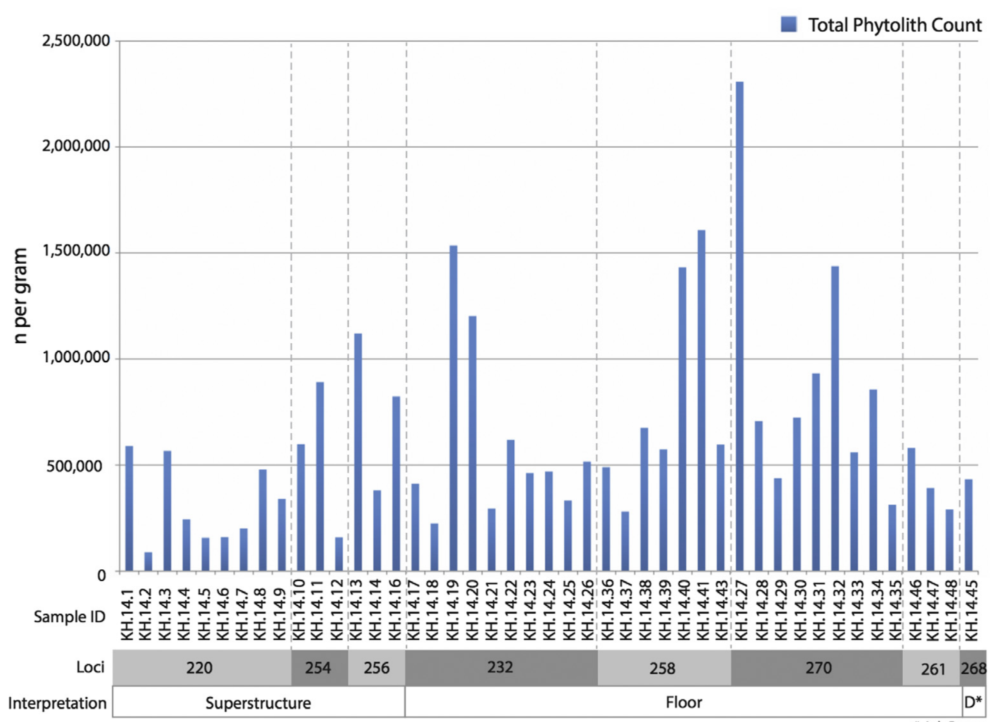

Fig. 8. Histogram of total phytoliths per gram of sediment at Kharaneh IV.

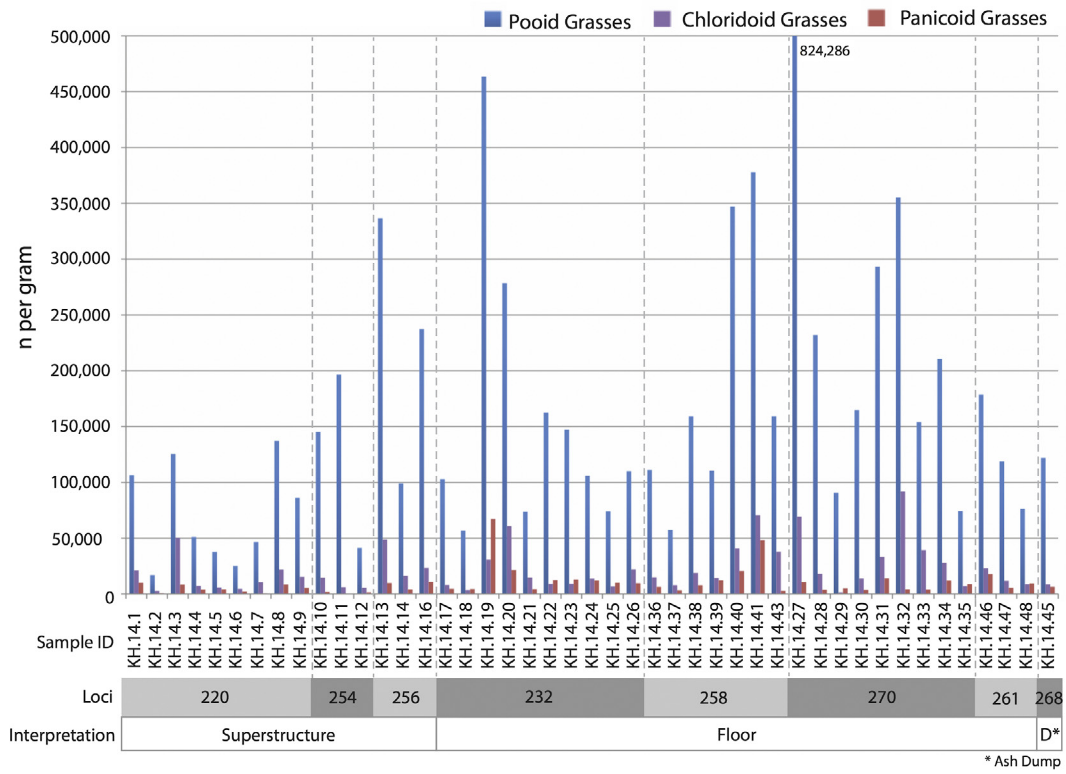

Fig. 9. Histogram of pooid, chloridoid and panicoid grass phytoliths per gram of sediment at Kharaneh IV.

Structures in the Great Basin were composed of two main parts, including a framework and a framework cover (Fowler, 1990), very similar to our understanding of how huts were constructed in the Levantine Late Pleistocene (Goring-Morris and Belfer-Cohen, 2003, 2008). While the framework was very consistent in form, the framework cover was more variable across the region (Fowler, 1990). To construct the framework, the long poles, measuring between three and four and a half meters, and between three to eight centimeters in diameter at the base, would first be arranged in a circle. The base of each long pole would be set twenty to thirty centimeters into the ground. As a general rule, a hut meant to house five to seven people, usually required a similar number of poles. Once the long poles were upright and set, three or four horizontal willow rings would be tied to the uprights to secure them. At the top of the hut, the last willow ring would serve as a smoke hole. Because of the scarcity of wood building materials for the house frames, especially the long upright poles, the house might be dismantled and reassembled if the family decided to move to another location (Fowler, 1990:113).

In the Levant, particularly the Eastern Levant, it is possible that the long wood poles for constructing the frame were at times difficult to source. It is plausible that similar curatorial behavior was practiced, however, as archaeological examples of the poles have not been recovered, this is not possible to investigate archaeologically. While the Great Basin structures are circular, evidence shows huts in the Levant tended to be oval or kidney shaped in outline, which may suggest that the frame was constructed differently, perhaps with shorter poles, or poles of varying lengths. Yet, it is important to note that unlike the Great Basin structures, no postholes were identified in or around the hut structures at Ohalo II or Kharaneh IV.

In the Great Basin, the framework could be covered in a variety of different ways, depending upon the availability of local resources. Throughout most of the Great Basin, sedges, reeds and cattails were usually gathered into bunches, along with grass, sagebrush and other vegetation, and then individually tied to the willow crossbars of the framework (Fowler, 1990:125). The bundles would then be held in place with a further set of horizontal willow rings (Fowler, 1989; Stewart, 1941). Another technique for covering the framework was to use mats, manufactured from cattail, sedges or reeds (Fig. 14) (Fowler, 1990:114). In the Plateau region, to the north west of the Great Basin, some groups would use multiple mat layers to cover their hut frames. For example, the Klamath and Modoc, would first cover the frame with reed mats (*Phragmites* sp.), followed by two different types of sedge mats, *Scirpus robustus*, followed by *Scirpus acutus* (Fowler, 1990:126–127). It is clear from the ethnographic sources that huts in the Great Basin could be covered with a variety of materials, but sedges, reeds and cattails were preferred, likely due to their inherent water repellant qualities (Fowler, 1990:132). It is plausible that Late Pleistocene hunter-gatherers in the Levant also recognized the favorable characteristics of these wetland resources. Moreover, in wetland/marsh environments, like the Azraq Basin, these resources would have been available in abundance. However, botanical evidence (macrobotanical and phytolith analysis) does indicate that a variety of monocot and dicot resources were employed in the hut thatching at both Ohalo II and Kharaneh IV. This 'variety' suggests that construction practices at Ohalo II and Kharaneh IV may have been more similar to the Great Basin huts covered with bundled thatching, rather than tule matting, although there is evidence at Ohalo II to suggest this technology was available (Nadel et al., 1994).

In any case, a vast quantity of tule and plant material would have been necessary to cover a hut frame. Nicholas (2007:56) suggests that 1000 tule or cattail plants would have been used to construct a small Plateau hut (wikiup). Observing that approximately 20 plants grow, on average, per square meter, he estimates that one structure would require approximately 200 square meters of dense tule/cattail bed. The impacts of such extensive tule harvesting would have been immediately apparent in the wetland. At Kharaneh IV, where three huts have been identified, we can estimate that harvesting up to 600 m^2 of dense tule bed may have been necessary. At Ohalo II, where six huts have been identified, we can estimate that up to 1200 m^2 of tule may have been necessary. This estimate assumes that tules were one of the preferred

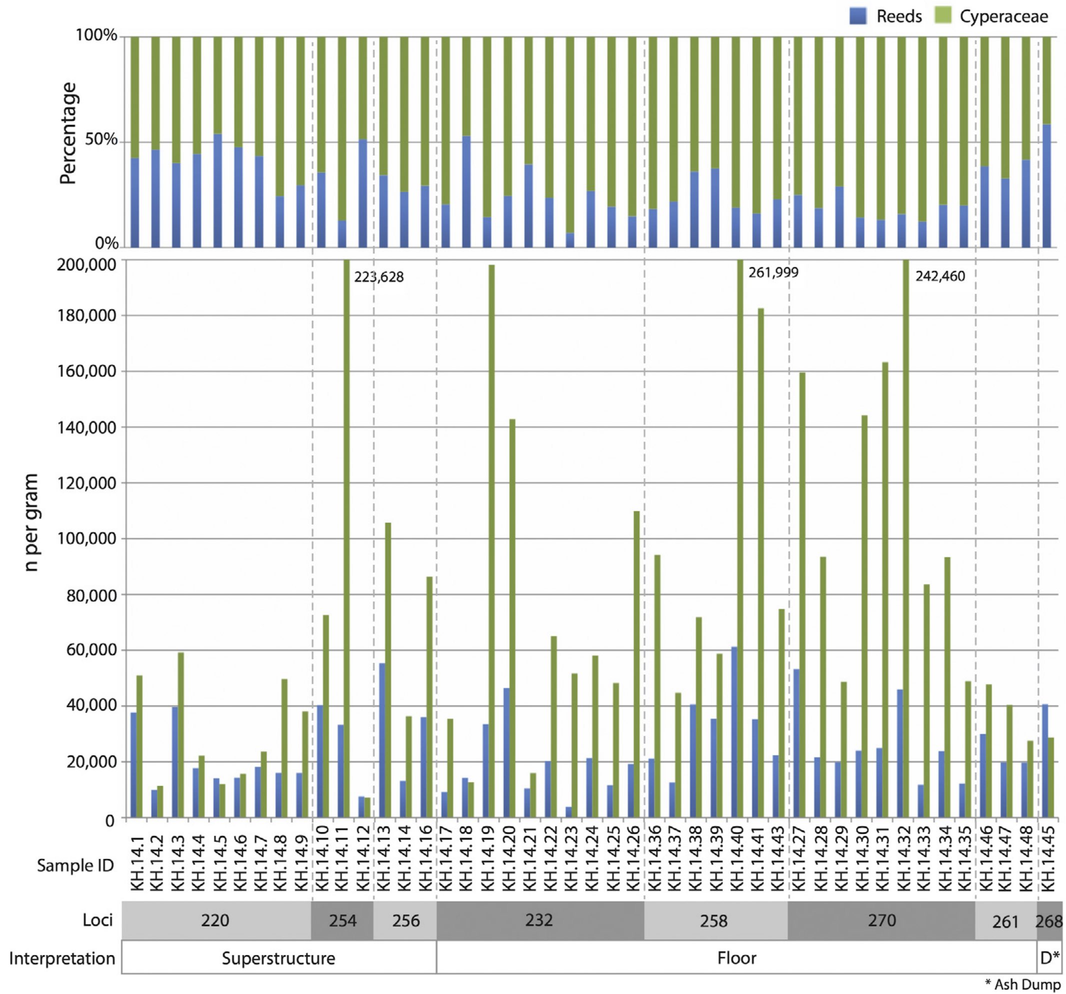

Fig. 10. Histogram of Cyperaceae and Reed phytoliths at Kharaneh IV. Single-cell and multi-cell evidence combined. Compared by percentage and per gram of sediment.

thatching materials, an interpretation the phytoliths appear to support.

In the Great Basin, the hut interior was arranged for sleeping, cooking and storage. Cattail leaves and grasses provided a cover for the floor, especially in cooler weather. Cattail leaves and grasses would also serve as bedding, which would be rolled against the wall during the day. In a clear space, usually in the center of the structure, a pit about 15 cm deep and half a meter in diameter was dug to contain the fire (Fowler, 1990:117–118). The interior floor deposits in Structure 1 appear to have featured a tule (sedge and reed) and grass cover for the floor. These same materials may also have been used as bedding. Kharaneh IV was inhabited during a period of persistent cool temperatures in the immediate aftermath of the Last Glacial Maximum. Consequently, it is not surprising that people would have employed a ground cover of some kind to insulate themselves and provide a more comfortable living environment.

Interestingly, in the Great Basin the entire house and camp were either abandoned or burned in the case of a death (Fowler, 1990:121). While we generally tend to conceive of hunter-gatherer settlement decisions as being motivated by resource availability, there is increasing evidence at sites like Kharaneh IV and Ohalo II for symbolic and ritualistic behavior and complex trade networks (Maher et al., 2012a, 2012b; Nadel, 2006; Richter et al., 2011b). These behaviors reflect a growing investment in place and suggest that social pressures, as much as environmental ones, may have increasingly impacted hunter-gatherer decisions.

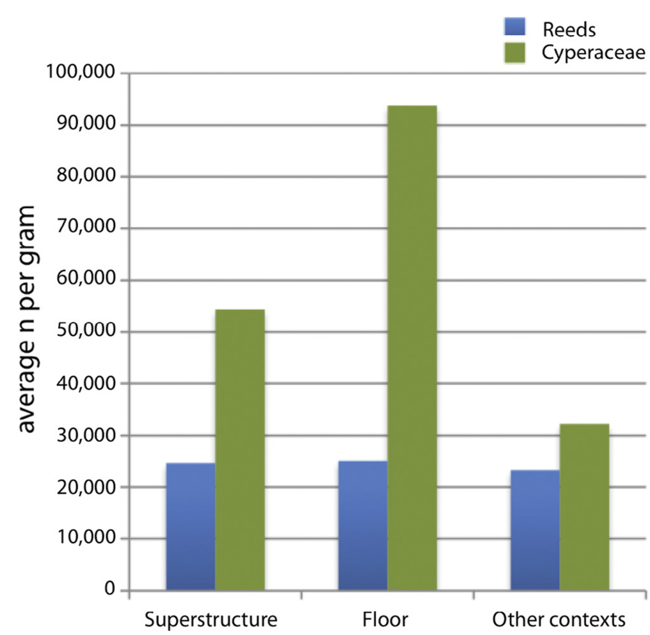

Fig. 11. Histogram of Cyperaceae and Reed phytolith averages from Superstructure, Floor and Other Contexts at Kharaneh IV. Single-cell and multi-cell evidence combined. 'Other Contexts' evidence is from the other non-hut Area B samples published in Ramsey et al. (2016).

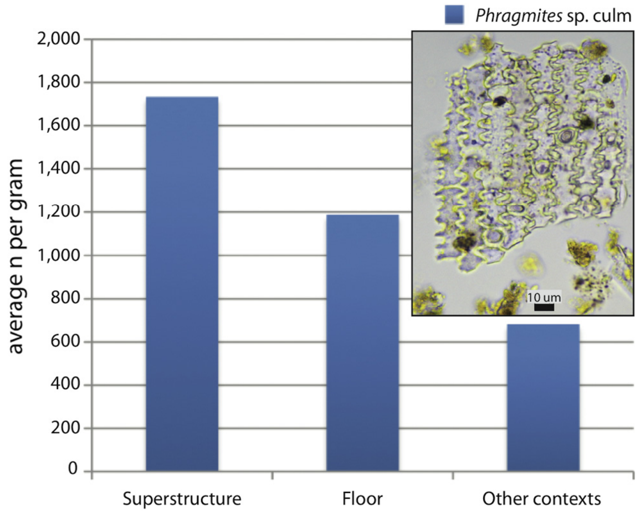

Fig. 12. Histogram of *Phragmites* sp. culm averages from Superstructure, Floor and Other Contexts at Kharaneh IV. 'Other Contexts' evidence is from the other non-hut Area B samples published in Ramsey et al. (2016). Image of Phragmites sp. culm from archaeological sample KH.14.46.

6.4. We shape our wetlands, and afterwards our wetlands shape us

The construction of these huts and the impact of these structures, visually as a building on the landscape and ecologically on the landscape due to the harvesting of materials to build the structures, would have been acute. Expanding on Winston Churchill's words "we shape our buildings and afterwards our buildings shape us" (Hansard, 1943), it is now recognized that we shape our environments, and afterwards our environments shape us. We then subsequently shape our environments, and this interaction continues (Laland and O'Brien, 2010; Laland et al., 2001; Odling-Smee et al., 2003). Accordingly, prehistoric evidence for increasing investment in place provides us with the opportunity to investigate and consider the dynamics and reactions initiated by the intensification of human-environment interactions within a circumscribed area. Wetland resources may have been extremely valuable because of their critical importance to the construction of these communities, both in building the structures and in supplying a reliable source of food and water. Rather fortuitously, sedge and reed resources tend to respond favorably to anthropogenic disturbance (Chambers et al., 1999, 2003; Cronk and Fennessy, 2001; Keddy, 2000; Keller, 2000; Ryan, 2009). Accordingly, and as initial evidence suggests (Ramsey et al., 2015), the collection of material and food resources from the wetland would have enhanced the ecological productivity of the landscape, and overtime, may have imbued that landscape with increasing economic and social meaning. Indeed, evidence for territoriality during this period, may be related to establishing ownership or stewardship over these predictable wetland resource locations (Smith, 2013:11).

7. Conclusions

Framed by ethnographic analogy, and macrobotanical and microbotanical evidence from Ohalo II, phytolith analysis was employed at Kharaneh IV to reveal how Early Epipaleolithic peoples in the Azraq Basin used local plant resources to construct their huts. The phytolith evidence suggests that Structure 1 at Kharaneh IV was constructed from a variety of plant species. The superstructure, like that of Hut 1 at Ohalo II, was likely composed of a woody dicot frame, and covered with a variety of shrubby herbaceous dicots. This interpretation fits the pattern described for other huts from this period (Goring-Morris and Belfer-Cohen, 2003, 2008). However, this phytolith analysis suggests that *Phragmites* sp. culm may also have been employed in the superstructure – perhaps as part of the frame. The phytolith evidence also demonstrates that a wide variety of grasses and wetland reeds and sedges were used in the construction, likely as bundled thatching to cover the frame, similar to construction practices in the Great Basin.

Moreover, the phytolith evidence indicates that the floors of Structure 1 featured a loose layer of soft vegetation, which included grasses and sedges. This vegetation may represent purposeful floor covering and furnishing of the hut interior, perhaps even formal matting and bedding, analogous behaviors have been observed in the Great Basin. These findings demonstrate the important contribution of phytolith analysis to our understanding of material culture and construction practices in the Late Pleistocene. These data add to a growing body of material and ecological evidence from the Azraq Basin that emphasizes a growing investment in place during the Late Pleistocene, and suggests that the construction of these *homes* may even have contributed to and enhanced the ecological productivity and social meaning of the Azraq Landscape.

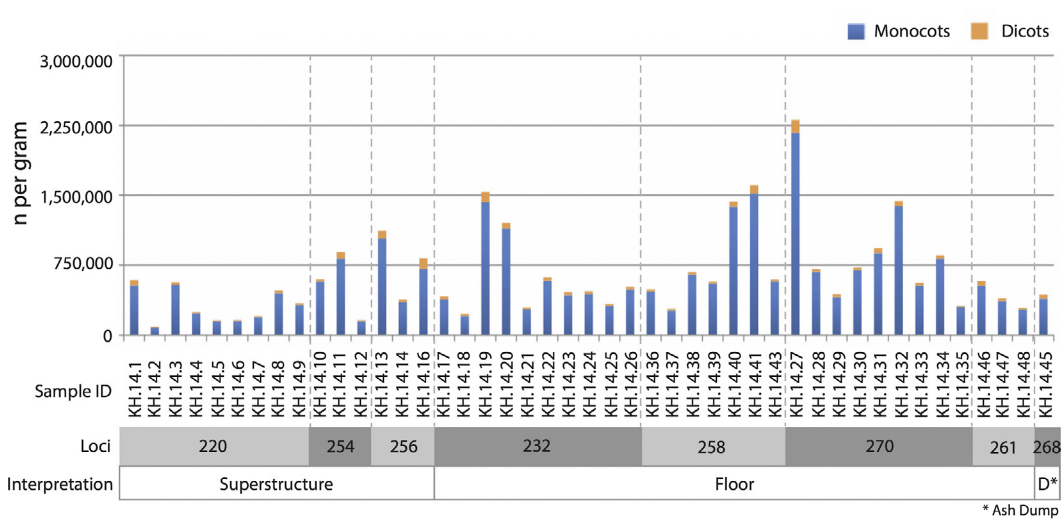

Fig. 13. Histogram of Monocots and Dicots per gram of sediment at Kharaneh IV.

Fig. 14. Northern Paiute cattail house. Photograph by Mary Freeman, Stillwater, Nevada, ca. 1900. Courtesy of Special Collections, University of Nevada, Reno Libraries.

Acknowledgements

Phytolith analysis and counting was conducted in the Environmental Archaeology Laboratory at the University of Texas at Austin. We thank Prof. Edward Banning (University of Toronto) for reading an earlier draft of this paper. His keen edits greatly improved the manuscript. We would also like to thank the Director General of the Department of Antiquities of Jordan for his support, our local Department of Antiquities Representatives for 2008–2010 (Ahmad Lash, Aref Daytham and Zuhayr al-Zubay), and the Kharaneh IV field crews of 2008–2010. We also thank the Council for British Research in the Levant for facilitating fieldwork in Jordan.

Funding

This research was supported by a Canadian Social Science and Humanities Research Council (SSHRC) Ph.D. fellowship [award number 752-2011-1728], a National Science Foundation SBE DDRIG [grant number BCS-1418462] (United States), and two Council for British Research in the Levant (CBRL) travel grants (2011, 2012) (United Kingdom) awarded to M.N. Ramsey. This manuscript was prepared during the tenure of M.N. Ramsey's Canadian SSHRC Post-doctoral Fellowship [award number 756-2015-0408]. The fieldwork at Kharaneh IV was funded by the Arts and Humanities Research Council (AHRC) (AH/E009484/1) (United Kingdom).

Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.jaa.2018.03.003.

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